SPECIFICATION

Docket No. 21140.001

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that We, George Rauscher, Charlie Mauldin and Laurie Hill, all citizens of the United States, have invented new and useful improvements in a

FORGED FLANGE CYLINDER LINER AND METHOD OF MANUFACTURE

of which the following is a specification:

"EXPRESS MAIL" NO. EV 125792855 US
I hereby certify that this paper or fee is being deposited with the United States Postal Service as "Express Mail Post Office to Addressee" service under 37 C.F.R. § 1.10 on the date indicated below and is addressed to the Mail Stop: Patent Application, Comm. for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.
Date of Deposit: Feb. 27, 2004 By: Sarah Horner

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to cylinder liners for internal combustion engines, particularly diesel engines, and to a method for manufacturing a cylinder liner blank.

2. Description of the Prior Art:

There is a continuing demand in internal combustion engine technology for increased horsepower and performance from such engines. Additionally, in order to meet environmental requirements for reduced emissions, internal combustion engines, including diesel engines, are being designed to operate at higher compression pressures and temperatures. Unfortunately, a direct correlation exists between the higher compression pressures and temperatures and heat production by the engine with a consequent increase in stress on the engine internal components. As a result of such factors as these, an upgrade of the engine block and associated components may be required. Such components include the "cylinder liners" which are the subject of the present invention.

Conventional diesel engines have replaceable cylinder liners of the flange-type which are inserted into the engine cylinder. Such sleeves facilitate machining and finishing on both the internal diameter and the outer diameter of the liner, which machining and finishing would be much more difficult to perform on the engine block itself. Cylinder liners also offer an advantage when the engine is rebuilt, since the liner can be replaced much more economically than the block.

The finished cylinder liner profile includes a flange or lip around one end where it seats on the face of the engine block. The finished cylinder liners are machined at the present time from stock called liner blanks. To avoid having to machine a significant thickness of material from virtually the entire OD length of the liner blank, the design calls for a thickened area to be formed onto the blank.

Typical industry practice for diesel engines is to use liners made from gray cast iron that includes the flange feature cast at the end of the liner blank.

In the manufacturing processes using gray cast iron, a thick cylinder is typically prepared of cast iron by a centrifugal casting method. The casting forms the cylinder sidewalls as well as a flange portion on the outer circumferential region at one end of the casting. However, these cast liners are not generally capable of withstanding the stresses induced by the operational conditions (increased pressures and temperatures) present in the latest generation of engine design, as discussed above.

One way to address this weakness is to require that the cylinder liners be made from steel, rather than from cast iron. Different techniques have been proposed in the past for producing a cylinder liner blank from a steel tube, including the thickened area for the flange. One prior art technique utilized a steel pipe with the flange portion of the cylindrical tube being formed by folding one end of the tube outward. A shortcoming of this technique is that the width of the flange wall cannot be enlarged because the flange wall is formed by folding the cylinder outward. Generally speaking, the thickness is smaller at the flange wall than at the cylindrical tube body so that the flange wall has a tendency to have an insufficient mechanical strength at the point of formation of the flange. In some cases, the flange wall strength obtained is insufficient due to fine cracking about the circumference at the point of the fold or roll. Also, the cylindrical tube is liable to be bent inward at the folded portion or in the vicinity thereof.

It has been suggested that a hot forging technique be devised for producing an upset on the cylinder liner blank to create the flange. However, as will be seen in the description of the invention which follows, it has been found particularly advantageous to utilize a forging process in which the forging is done with the metal in the cold condition, as opposed to upsetting using a hot forging process.

A need exists for a method for manufacturing a cylinder liner blank of the type used to form a cylinder liner for an internal combustion engine which cylinder liner meets and exceeds the requirements for today's increased temperature and compression requirements.

A need also exists for such a manufacturing method which produces a cylinder liner blank from a carbon steel alloy which liner is forged in a cold forging process.

A need also exists for an improved cylinder liner blank which is produced by the aforesaid cold forging process as will be described.

SUMMARY OF THE INVENTION

In the method of the present invention, an improved cylinder liner blank is provided for an internal combustion engine, particularly a diesel engine, in which a cold forging process is utilized to form the flanged region of the sidewall of the cylinder liner blank. The method of manufacture of the invention is used to produce a cylinder liner for an internal combustion engine including a cylinder block having at least one cylinder bore. In the first step of the invention, a cylindrical tube is produced from a carbon alloy steel. The cylindrical tube has generally cylindrical sidewalls, an internal diameter and an external diameter, and an overall length based upon predetermined starting dimensions as dictated by the end application for the cylinder blank.

The cylindrical tube is cut or otherwise dimensioned to the starting dimensions of the unforged cylinder liner blank. The unforged cylinder liner blank is placed into a hydraulic press and cold formed into a forged cylinder liner blank. The cylinder liner blank includes a liner body with cylindrical sidewalls which define an internal diameter, an external diameter, a cylindrical lower extent and a flanged or upset region at an upper extent thereof which is integrally formed in the cold forging process. The flanged region of the cylinder liner blank extends radially outwardly relative to the external diameter of the cylindrical sidewalls of the cylinder body so as to define a stop shoulder, the stop shoulder being cooperatively received in abutting relation to a mating surface defined by the cylinder bore of the internal combustion engine.

Preferably, the cylinder blank is formed from a carbon alloy steel having a carbon content of at least about 0.25%, more preferably greater than about 0.50%. In a particularly preferred embodiment of the invention illustrated herein, the cylinder blank is formed of 1055 carbon alloy steel. The forged cylinder blank has an internal diameter in the range from about 3 to 8 inches in most cases.

In a particularly preferred method of the invention, the unforged cylinder liner blank is placed into a forging die of a hydraulic press. The hydraulic press has a forging die with a die cavity for

receiving the cylinder liner blank and an upper, flange cavity of greater relative diameter than the die cavity. A closely fitting forming mandrel is received within the internal diameter of the cylinder liner blank within the forging die. A hydraulic force is then applied to the unforged cylinder liner blank in the forging die by means of a forging die cap to thereby cold form an integral flanged region on the cylindrical sidewalls of the cylinder blank at an upper extent thereof. The cold forging step includes applying anywhere from about 500 to 1,000 tons of hydraulic force to the cylinder liner blank to cause the carbon alloy steel to flow into the flange cavity to form the flanged region of the cylinder body.

A method of assembling an internal combustion engine is also described, the engine having a cylinder block and at least one cylinder bore. In the method of assembly, a forged cylinder liner blank of the type described is first machined to a finished state to form the finished cylinder liner. The finished cylinder liner is then concentrically disposed at a location within the cylinder bore and secured to the cylinder block. The flanged region of the cylinder liner so formed extends radially outwardly relative to the external diameter of the cylindrical sidewalls of the cylinder body so as to define a stop shoulder, the stop shoulder being cooperatively received in abutting relation to a mating surface defined by the cylinder bore of the internal combustion engine.

Additional objects, features and advantages will be apparent in the written description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified, side sectional view of the hydraulic press and die set used to cold forge the cylinder liner of the invention.

Figure 2 is partial sectional view of a portion of the die set of Figure 1, showing the flange forming step of the invention.

Figure 3 is an isolated view of a longitudinal section of the cylinder liner of the invention showing the relative hardness values for various regions of the cylinder liner blank after cold forging.

Figure 4 is a picture of the grain flow taken from a slice of a cylinder liner blank made according to the method of the present invention.

Figure 5 is a photograph at 100X of the microstructure of the straight cylinder area of the liner blank of Figure 4.

Figure 6 is a view similar to Figure 5 at 100X of the forged, flange area of the cylinder liner blank.

Figure 7 is a partial, cross sectional view of a typical prior art finished cylinder liner for a diesel engine.

Figure 8 is a side, cross sectional view of an exemplary cylinder liner blank for a diesel engine showing the relative dimensional relationships thereof.

DETAILED DESCRIPTION OF THE INVENTION

Turning first to Figure 7, there is shown a prior art diesel engine cylinder arrangement for an internal combustion engine. The piston cylinder shown in Figure 7 is typical of the prior art and is intended to explain the general environment of the present invention. The power cylinder 10 shown in Figure 7 is part of a conventional (and thus not illustrated) diesel engine. Such engines usually have a cylinder bore diameter in the range from about 3 to 8 inches.

The power cylinder 10 is received within the block 12 of the engine and includes a cylinder liner 11 of the type under consideration in the discussion which follows. The liner 11 slidably receives the piston assembly 15 which may vary in construction, depending upon the type of vehicle, pump, or engine under consideration. The upper extent of the cylinder liner 11 is enclosed by a conventional cylinder head 16 secured against the liner and block and sealed by a head gasket 17 to define, with the upper side of the piston assembly 15, a combustion chamber 19. The piston assembly 15 is connected in the usual manner to the engine crankshaft (not shown), as by connecting rod 20.

In the particular arrangement illustrated in Figure 7, the piston assembly 15 comprises a piston 21 of generally conventional design for diesel engines. The assembly includes a trunk type piston constructed of cast or forged aluminum alloy having an insert 22 made of an impact resistant material which is compatible to the aluminum alloy in its coefficient of thermal expansion and other properties. A top ring groove 24 is machined to receive a top compression ring 25 of the split annulus type. Beneath the top ring groove 24, a second keystone-shaped ring groove 26 is machined in the aluminum alloy piston body to receive the second compression ring 27 also of the split annulus type. Beneath the second ring groove 26, a third rectangular groove 28 is machined in the aluminum piston in which a conventional oil control ring 29 is received. As is conventional in the art, the piston 21 contains an internal cavity (not shown) conventionally cooled by an oil jet spray, from which the top and second ring grooves 24 and 26 are isolated. The oil ring groove 28 customarily has small holes drilled into the cavity to permit the drainage of oil. Beneath the oil control ring

groove 28, the piston comprises the customary skirt 30 for effecting the usual guiding fit of the piston with the walls of the cylinder 11. Although a trunk type piston has been described it will be evident that the invention will be equally applicable to other type piston designs, as well. The description of the piston assembly 15 is not intended to be limiting of the scope of the present invention, but is merely intended to explain the operating environment of the cylinder liner 11.

The cylinder liner 11, shown in Figure 7, is machined from a blank, as shown in Figure 8, and includes a cylinder liner body having cylindrical sidewalls 31 which define an internal diameter 33 and an external diameter 35 for the liner body. The body also includes a cylindrical lower extent 37 (shown broken away in Figure 7) and an upper, flanged or upset region 39. The present inventive method is directed toward a process for providing the cylinder liner 11 with a flanged or upset region 39 in which a forging process, preferably a cold forging process, is applied to a class of carbon alloy steels. Although the invention is not limited to particular cylinder liner dimensions, the prototype dimensions shown in Figure 8 are as follows (all dimensions being in inches):

$d1 = 5.26$
$d2 = 6.39$
$d3 = 6.73$
$l1 = 10.93$
$w1 = 0.598$

The method of forming the cylinder liner blank of the invention will now be described, primarily with reference to Figures 1 and 2. In the first step of the method, a cylindrical tube is formed from an alloy steel. The cylindrical tube can be formed in any convenient manner. For example, the cylindrical tube can be formed by machining a solid bar stock of steel to provide a cylinder liner blank having the required starting dimensions. Alternatively, a seamless carbon alloy steel tube can be provided directly by the steel mill for use in the process of the invention. The starting tube would then be cut to the desired size. In this case, for example, a 20 foot starting tube might be cut into

individual tubes of approximately 10 ½ inches in length. The required starting dimensions will depend upon the particular application, however. By way of example, the final dimensions of the cylinder liner above may be used for comparison.

The unforged cylinder liner blank (41 in Figure 1) is then placed within the forging die set 43 of a hydraulic press 45. The forging die set 43 includes a forging die cavity 47 for receiving the unforged cylinder liner blank and has an upper flange cavity 49 of greater relative diameter than the die cavity. As shown in Figure 1, a closely fitting forming mandrel 51 is received within the internal diameter 33 of the unforged cylinder liner blank.

In the next step of the method, hydraulic force is applied to the unforged cylinder liner blank in the die cavity by means of the forging die cap 53 to thereby cold form an integral flanged region (39 in Figure 2) on the cylindrical sidewalls of the cylinder liner blank at an upper extent thereof. As shown in Figure 2, the flanged region 39 extends radially outwardly relative to the external diameter of the cylindrical sidewalls of the cylinder body so as to define a stop shoulder (55 in Figure 8). The forged cylinder liner blank would then receive any final machining of the type normally applied to cylinder liner blanks for the particular engine application at hand in order to form the finished cylinder liner. The stop shoulder 55 formed in the forging process is cooperatively received in abutting relation to a mating surface, such as an annular shoulder (61 in Figure 7) defined by the cylinder bore of the internal combustion engine. The upper extent of the cylinder liner is dimensioned so as to form a close interference fit (i.e. 0.0005 to 0.0015 inch clearance) with the cylinder bore. The finished cylinder liner is secured in place by the cylinder head and head bolt clamp load in a conventional manner when installed within a diesel engine.

Although a variety of starting materials can be utilized for the cylinder liner blank 41, the preferred materials for the diesel engine cylinder liners of the invention are carbon alloy steels. Preferably, the carbon alloy steels have a relatively high carbon content, generally greater than about 0.25%,

more preferably greater than about 0.50%. The most preferred material for the particular application illustrated is a 1055 carbon alloy steel having a carbon content of approximately 0.55%.

The hydraulic force applied by the press can range anywhere from about 500 tons to 1,000 tons, depending upon the starting material and ultimate dimensions of the finished product. Although the process is a cold forging process and can be carried out without heating the cylinder liner blank, there may be applications in which the upper extent of the cylinder liner blank is heated, as by induction heating, in the range of about 1200°F to reduce stress during the cold forging process to thereby increase the useful production life for the hydraulic die and forming mandrel.

The following example is intended to be illustrative of the invention without limiting the scope thereof:

EXAMPLE I:

A prototype run was conducted to determine the forging process parameters for a cylinder liner for diesel engine application. The forged cylinder liner blank was produced by cold forging from a starting cylinder liner blank of 1055 carbon steel alloy using the previously described method steps. Testing was then performed to check for grain flow and for any folding back of material at formed area. No target hardness values were specified, but attention was given to any difference in hardness at the formed area versus the non formed area of the cylinder liner. For the prototype run, a 3.500 inch external diameter bar was used.

Starting Material:
The original material was 3.5"OD solid bar stock, heat number D39421. The material was machined into a cylinder having an internal diameter of 2.490 inches, an external diameter of 3.400 inches and an overall length of 3.000 inches.

Tooling:

The forging tool material was 4140 steel, heat treated to the hardness required to deform the 1055 carbon alloy starting cylinder liner blank.

Process:

The process was a cold forging process performed on a hydraulic press.

Process Evaluation:

One of two parts made was cut and metallurgically evaluated. A grain flow slice was removed, polished, and macro etched to determine material flow lines. A picture of the grain flow is presented in Figure 4. Due to insignificant amount of deformation and clean material, there were no obvious flow lines visible. The microstructure of the flanged insert is illustrated in Figures 5 and 6. Both the upset (flange) area, Figure 6, and the undeformed straight cylinder area, Figure 5, were evaluated. The flange area shows slightly elongated grains as compared to the straight cylinder area. The photomicrographs represent as-received material from the mill and no heat treatment was performed.

The hardness survey (Figure 3) shows some difference between the flanged region and the remaining undeformed cylinder. The slightly higher values in the flanged region are a result of the cold working during upsetting.

An invention has been provided with several advantages. The method of manufacture of the invention shows that carbon alloy starting blanks can successfully be cold forged to create the flanged cylinder liners of the invention. There are no visible forging defects such as laps, foldovers, or undesirable material flow. Slightly higher hardness values were observed in the flanged area due to cold upset, but no undesirable overall effects were realized. The cold forged cylinder liners of the invention, formed from carbon steel alloys, provide the structural integrity needed for many of today's internal combustion engines which operate at higher compression temperatures and pressures. The manufacturing process is simple to implement and economical to carry out.

While the invention has been shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit thereof.